# WINTER WHEAT GROWTH UNIFORMITY MONITORING THROUTH REMOTE SENSED IMAGES

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## ABSTRACT

Winter wheat growth uniformity is important for the yield and grain quality evaluation of field. The traditional investigation of crop uniformity is mainly depends on manpower in China. Remote sensing technique is a potentially useful tool for monitoring the crop uniformity status during the crop growth season. The objective of this study was to evaluate the winter wheat growth uniformity for the winter wheat fields through multi-temporal remote sensing imagery. Three Landsat5 TM images at winter wheat tillering stage, jointing stage and milk stage were collected and processed. The NDVI (normalized difference vegetation index) decision tree was used to extract the winter wheat field for all images. Then, combined the winter wheat field vector information, the CV (coefficient of variation) of NDVI for each fields are calculated. A new index GUNI (growth uniformity normalized index) based on the NDVI CV was introduced to evaluate the uniformity of winter wheat growth for different growth stages. The uniformity variation maps were conducted to show the winter wheat growth uniformity changes for all fields between different growth seasons. The study results indicated that the winter wheat growth uniformity at jointing stage was more obviously than that of at tillering stage and milk stage. Fields where the GUNI value higher in tillering stage will grow better than others field in jointing stage and milk stage. It can be seen that remote sensing data was feasible to investigate the crop growth and GUNI can indicate the growth uniformity of fields well.

**Key words:** Winter wheat, Growth uniformity, NDVI, GUNI

## INTRODUCTION

An uneven growing winter wheat will be slower to reach full ground cover and lead to uneven yield and quality for field. So monitoring the wheat growth uniformity information is important to both farmers and food processing enterprises. At present, farmers and inspectors often visually assess crop growth uniformity or samples under strict rule for growth uniformity evaluation (A.G. Ma, et.al, 2001, Q.Z. Zhong, et.al, 2001, L.H.,Yang and R.K. Ma, 2006). Determining growth uniformity through quantitative measures is a poorly researched area and there is little documented literature on the subject. Development of quantitative methods to determine growth uniformity in crop will greatly benefit the farmers, managers, and food producers alike.

Along with the development of remote sensing technology, satellite remote sensing has become an important tool for monitoring and management of agriculture (Moran, 1997, Serrano et al,2000, Wood et al,2003). It allows us to obtain a complete picture of all parts of an area and check crop growth at a given time. The vegetation index calculated by red and near-infrared bands of remote sensing image NDVI (normalized difference vegetation index), which positive correlated with crop leaf area index (LAI), the crop photosynthetic and biomass, was widely used to monitor the wheat growth and yield assessment (Wanjura and Hatfield,1987, Baret and Guyot,1991, Carlson and Ripley,1997, F. Baret et al, 2001, P,Gong et al,2003).

This paper focuses on the crop growth uniformity monitoring through remote sensing technique. An image analysis-based method was developed to determine crop growth uniformity from remote sensing images. A new index GUNI (growth uniformity normalized index) based on the NDVI variation was introduced to evaluate the uniformity for different fields. Then multi temporal Landsat TM remote sensing images were used to analyze the change of wheat growth uniformity for different growth season.

## MATERIALS AND METHODS

### Study area

The study were conducted at the Tongzhou district, the main winter wheat planted areas of Beijing municipality, where located in 39.59 º ~ 40.03 º N and 116.51 º ~ 116.95 º E (figure 1).

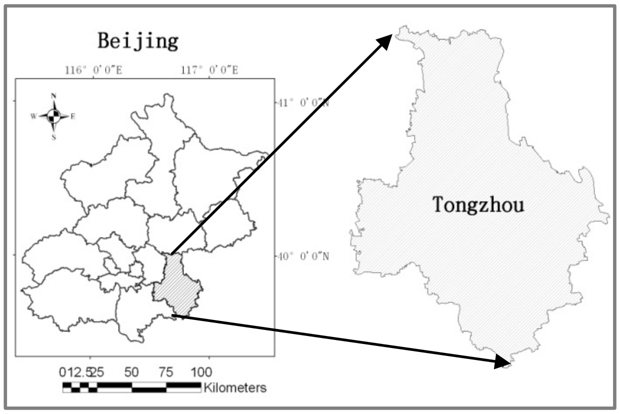


**Fig.1.Location map of study area**

The study area is in a dry sub-humid region with an annual mean precipitation of 550 mm. Between 70 and 80% of the precipitation occurs between July to September. Winter wheat (Triticum aestivum L) is the main crop planted in Beijing area. The main wheat varieties are Jing 9428, Nongda 3432, Jingdong 9843, Nongda 211, Jingdong 8, and Jingdong 12. It is usually sown on late of September and harvested on middle of June the next year.

## Data acquisition

### Remote sensing images acquired and processing

In 2008, three Landsat TM remote sensing images were acquired during the winter wheat growing season. Acquisition time were on March 27, April 28 and May 30, respectively corresponding to the winter wheat setting stage, the flowering period and milking stage. In addition, one Indian satellite ISP6 image on July 12, 2008, was acquired after the winter wheat had been harvested.

To ensure data quality, all remote sensing images were preprocessed before data analysis. Image processing included radiometric calibration, atmospheric correction and geometric correction. Radiometric calibration was carried on with Landsat calibration of ENVI software (ENVI4.1, 2003). After the radiometric calibration, the DN values of Landsat TM image was turned into radiance at top of the atmosphere. Then FLAASH (Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes) software model which based on MODTRAN4 was used for atmospheric correction for all images (Song et al, 2005, Matthew et al, 2003). Lastly, geometric correction was carried on for each imges based on Beijing maps (1:50 000). More than 200 control points were selected in each image and the error of geometric correction was controlled within 1 pixel.

### Vector field data

The ancillary vector data used are the 2006 field use map of Beijing area at scale 1:5000 produced from original film of aerial survey and geo-coded into Xi'an 1980 coordinate system complying with the 1985 National Height Datum of China. For winter wheat field boundary vector data update applications, Landsat5 TM images of 2008 was used to detect the change of vector data of winter wheat field boundary.

## ANALYTICAL METHODS

### Definition of growth uniformity normalized index (GUNI)

Growth uniformity normalized index (GUNI) based on the NDVI CV was introduced to evaluate the change of winter wheat growth uniformity for all fields between different wheat growth seasons in this study. In order to calculate the field GUNI, the field boundary vector data was used to extract the pixels from NDVI images. The spatial resolution of Landsat5 TM image is 30m so there were several NDVI pixel points of 30m×30m lie in the field, showed as figure 2. Then, for each field, field polygon data was used boundary to calculate the mean value, standard deviation value and the variation coefficient (CV) of those NDVI points.

The definition of GUNI was as follows.

$$\mathrm{GUNI} = 1 - \frac{NDVI_{CV}}{(NDVI_{CV_{\max}} + NDVI_{CV_{\min}})} \tag{1}$$

$NDVI_{CV}$ was NDVI variation coefficient for the study wheat field;

$NDVI_{CV\min}$ was the minimum of NDVI variation coefficients of all wheat fields of same growth season;

$NDVI_{CV\max}$ was the maximum of NDVI variation coefficients of all wheat fields of same phase.

NDVI CV, the ratio of the NDVI standard deviation and the average value, can indicate crop growth uniformity situation for a crop fields. In this paper, we constructed winter wheat growth uniformity normalized index (GUNI) according to the NDVI CV of all fields in one remote sensing image. It was designed to evaluate the uniformity of winter wheat growth for all fields because it is the normalized value for different fields at the same wheat growth season. GUNI value ranges between 0-1 with no unit. The high GUNI value stands for good growth, with high NDVI value and more uniformity. Generally, the higher the GUNI value, the better the crop growth community.

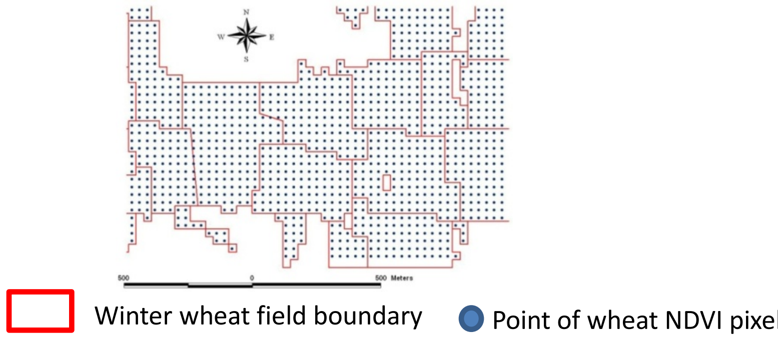


**Fig.2. Sketch map of winter wheat fields boundary and NDVI points**

## Research methods

The GUNI value for the winter wheat fields was calculated through remote sensing images in order to evaluate and compare the growth uniformity status for the winter wheat fields between different seasons. The analysis procedure and study methods flow chart was shown in figure 3.

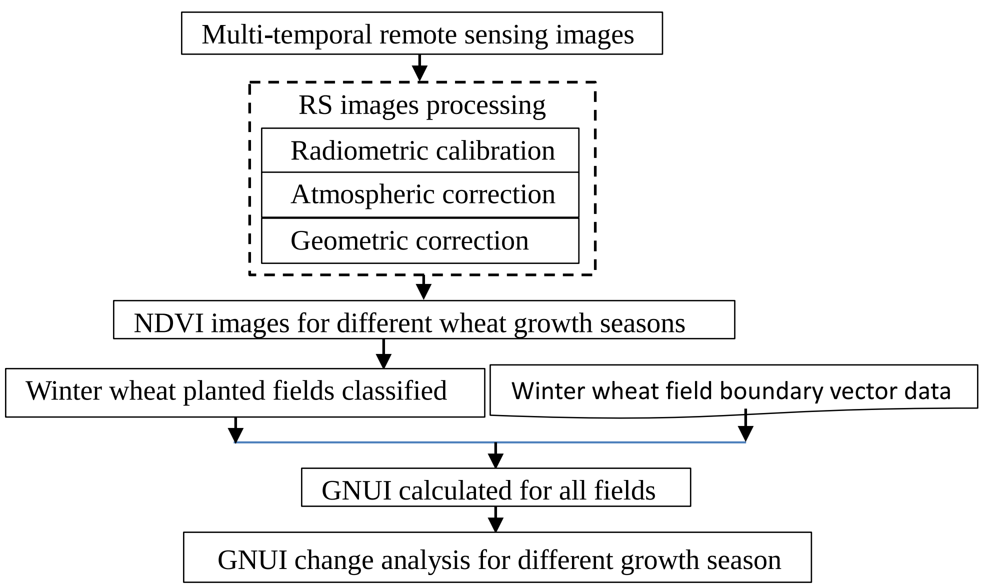


**Fig.3. Analysis flow chart for the study**

For this study, three Landsat TM5 images and one ISP6 image at different growth season were collected for winter wheat classification and uniformity evaluation. After the images pre-processed, NDVI values was calculated from the remote sensing images. Then the decision classification method (SHEN et al, 2007, PAN et al, 2009) was used to extract winter wheat fields. Raster image of winter wheat fields was then convert to vector boundary data through the software of Defimiens (Definiens 7.0, 2009). Lastly, GUNI value was calculated for each winter wheat fields in the study area and GNUI change for different growth season was then analyzed for those fields.

## RESULTS AND DISCUSSION

### Winter wheat fields extraction and GUNI calculation

In Tongzhou area, winter wheat tillering stage often lasts from early March to late March. The winter wheat jointing stage can continue for several weeks till to middle or late of April depending on the planting date and weather conditions. Winter wheat achieves full canopy at May. At this stage, the wheat plant becomes strongly erect. Bloom occurs 5 to 7 days after heading, and the grain fill period of wheat is typically lasts 30-40 days in study area. The mature wheat is often harvested on middle of June. Figure 4 shows the wheat growth in different periods. NDVI of winter wheat fluctuates with the change of wheat growth. Value of NDVI firstly increases from March to April. It reach the highest at the early-middle of May. Then the value decreased gradually in the following several weeks with the maturation of the wheat grain. The roll crop of winter wheat in Beijing area is summer corn, it is planted on late of June in the fields where the wheat has been harvested. The NDVI value for the corn is little than other plants because the corn canopy coverage is low in July.

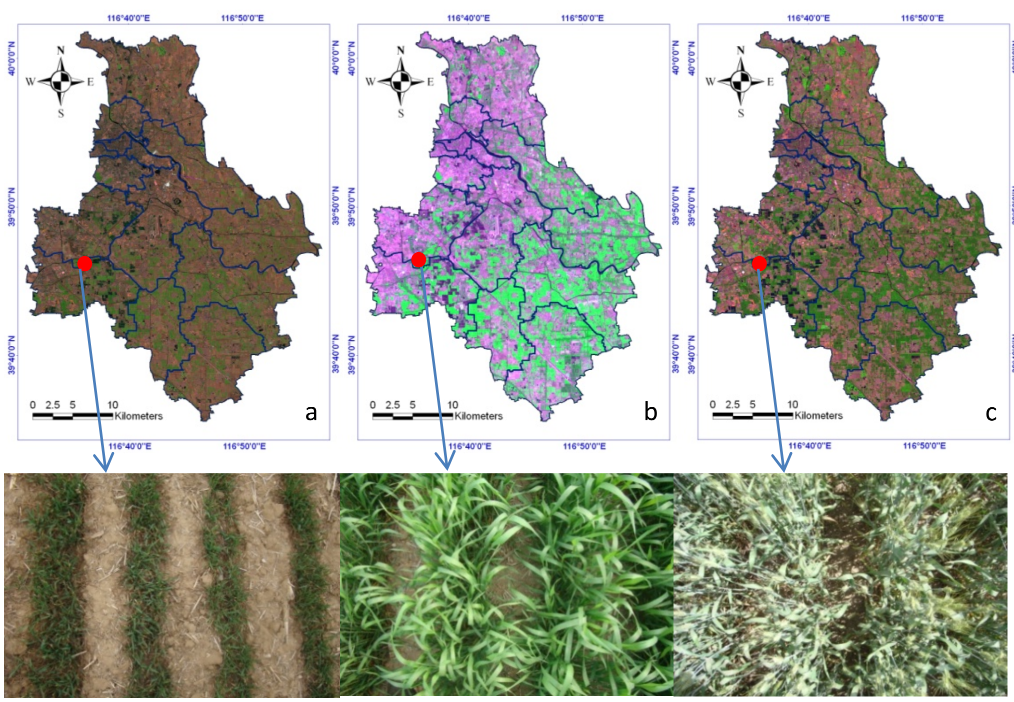


**Fig.4. RS images for different winter wheat growth stages and corresponding photos of the winter wheat Beijing area.**
**a.** RS image of 27$^{th}$ March **b.** RS image of 28$^{th}$ April **c.** RS image of 30$^{th}$ May

This character of NDVI variation for wheat fields can be used to distinguish the winter wheat to other plants such as the spring corn, spring bean, purple medic and vegetables in this study. Decision tree was established based on the threshold of on the four images NDVI value, show as in figure 5.

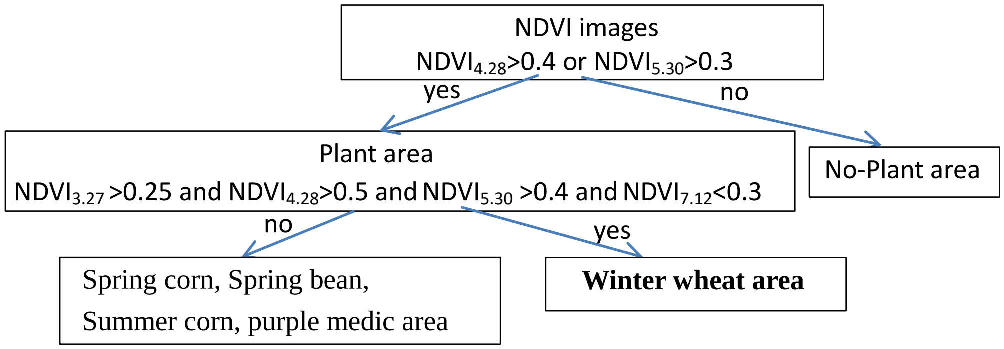


**Fig.5. Decision tree of winter wheat classification**

Winter wheat fields classifies results of winter wheat is shown in figure 6a.

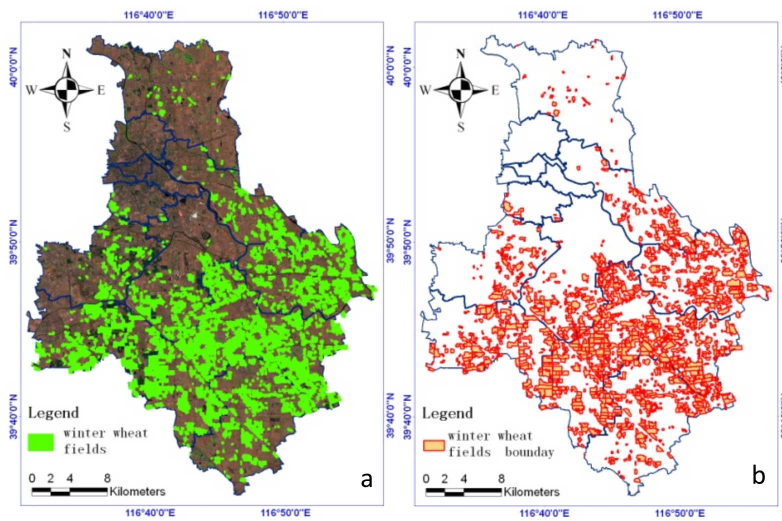


**Fig.6. winter wheat classification result (a) and wheat fields vector boundary (b)**

Raster image of winter wheat fields was then convert to vector boundary data. The results showed in figure 6b. Study indicates that total area of winter wheat was 17791 hectares in 2008. There were 526 pieces of wheat fields with less than 10 hectares, 394 pieces with 10-30 hectares, 130 pieces with 30-70 hectares, 2 pieces with more than 70 hectares.

## GUNI evaluation for Tongzhou area

Then the GUNI value for each filed in different growth stages were calculated through the formulae (1). The GUNI images for three stages are showed in figure 7. The images show the spatial distribution of fields with different GUNI value. From those maps, it can be easily found that which fields is at high (red color fields) or low uniformity wheat fields (the green color fields).

Then statistical analyzed the GUNI frequency for all wheat fields at different growth stages, the results shown as figure 8. Table 1 indicates the GUNI min, max, mean and standard deviation value for all wheat fields in Tongzhou district on March 27 (winter wheat tillering stage), April 28 (winter wheat jointing stage), and May 30 (winter wheat milk stage).

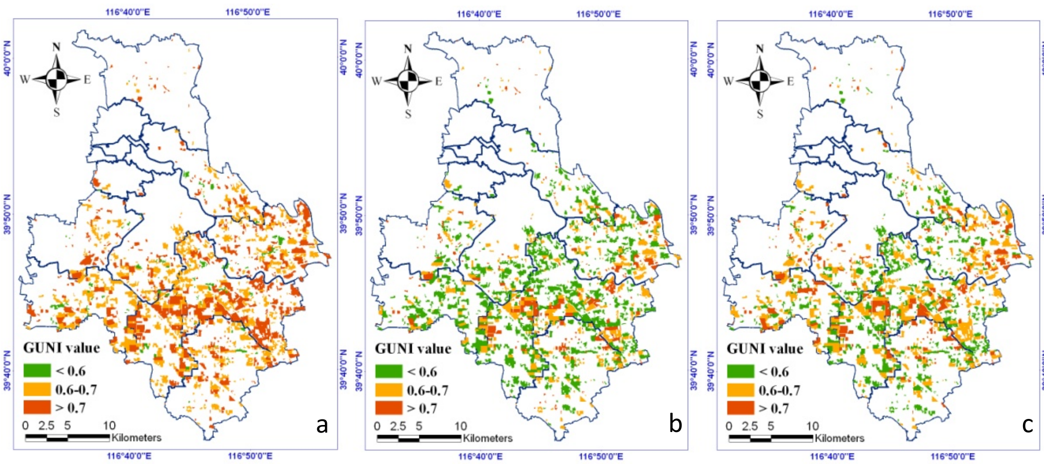


**Fig.7. winter wheat fields GUNI maps for different growth stages**
**a.** Tillering stage **b.**Jointing stage **c.**Milk stage

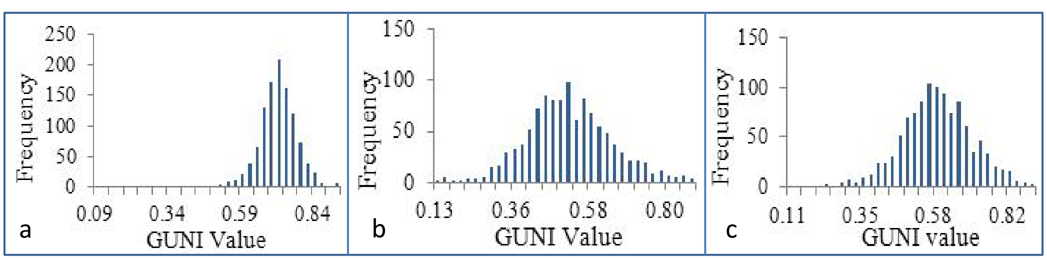


**Fig.8. winter wheat fields GUNI frequency maps for different growth stages**
**a.** Tillering stage **b.**Jointing stage **c.**Milk stage

**Table 1.** The statistical table of GUNI value of winter wheat fields in different stages

| Name \ Statistics value | The minimum | The maximum | Mean | Standard deviation |
|---|---|---|---|---|
| 3.27 GUNI | 0.090 | 0.910 | 0.695 | 0.066 |
| 4.28 GUNI | 0.130 | 0.868 | 0.503 | 0.121 |
| 5.30 GUNI | 0.110 | 0.890 | 0.571 | 0.113 |

GUNI mean was 0.695 at the tillering stage, and it decreased to 0.503 at the jointing period, then increased to 0.571 at the milk stage. The maximum standard deviation value of winter wheat GUNI was 0.121 at the jointing stage. The minimum was 0.066 at the tillering stage. It can be seen from the table, the growth variation is more distinct at the jointing stage than at the wheat setting and milk stage. At the tillering stage, we can see from the photo of figure4, the winter wheat was in low coverage, it's spectrum reflectance was severe affected by the bare soil. In the wheat milk stage, the ear of wheat and yellow leaves also reduce the difference of wheat growth variation in spatial. It can be seen that growth uniformity in winter wheat jointing stage is more obviously than that of in tillering stage and milk stage. The new index of GUNI is effectively in monitoring and evaluation the growth uniformity for different fields.

## GUNI change evaluation

The GUNI change was defined by the difference of GUNI value between images of conjoint stage. The result was shown in figure 9a and 9b. It can be seen from the images that the uniformity of most winter wheat fields decreased from tillering stage to jointing stage, while it increased from jointing stage to milk stage. Then, the wheat fields uniformity evaluation map (figure 9c) was processed through the summary of figure 9a and 9b.

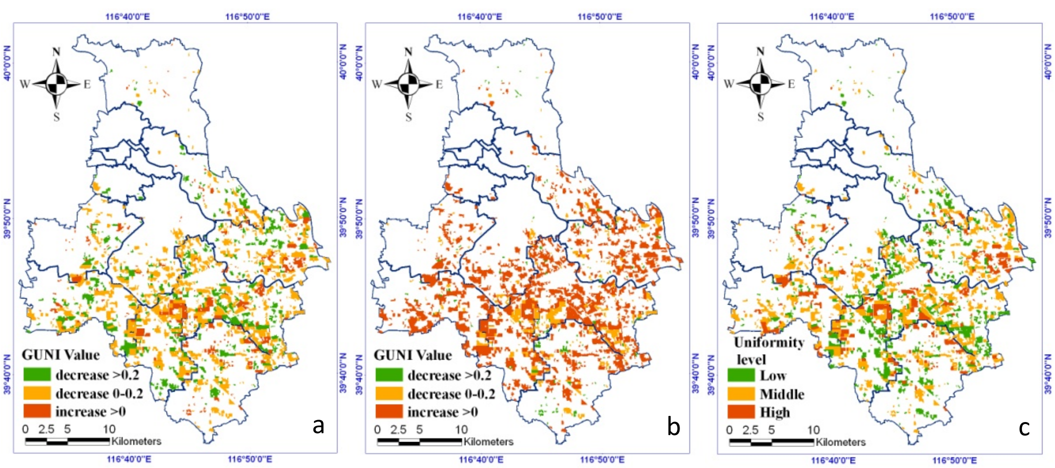


**Fig.9. winter wheat fields GUNI change maps between different growth stages**

**a.** Tillering to joint stage GUNI change **b.** Jointing to milk stage GUNI change map **c.** uniformity evaluation

## Conclusion and discussion

This study attempts to monitor and evaluate winter wheat growth uniformity through multi-temporal remote sensing imagery. A new index GUNI (growth uniformity normalized index) based on the NDVI CV was introduced to evaluate the growth uniformity of different fields in three winter wheat growth stages. The study indicates that the growth uniformity in winter wheat jointing stage is more obviously than that of in tillering stage and milk stage. Fields where the GUNI value higher in tillering stage will grow better than others field in jointing stage and milk stage. The new index of GUNI is effectively in monitoring and evaluation the growth uniformity for different fields.

Our study proposed a method for winter wheat growth uniformity monitoring base on the RS image which can be used for other crops. It also needs to be extended by further intensive and in-depth research of the method of the yield and grain quality uniformity monitoring. In addition, there should be further studies to include other environmental features that influence crop growth uniformity, such as irrigation water, plant diseases and insect pests. The application and use of this method for farm managers may require help from professional personnel for RS data processing and analysis. Therefore, it is necessary to develop simple software for users to popularize this method in the future.

## ACKNOWLEDGEMENTS

This work was financially supported by program of ‘technology of remote sensing key indicators for cultivated land quality monitoring’ (2012BAH29B01) from the national science and technology support program, National Natural Science Foundation of China (31071324).

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